Ecological Risk Assessment of Persistent Organic Pollutants in Wetlands of the Remediated Sydney Olympic Park, NSW, Australia

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Certificate of Authorship/Originality

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements of a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis

Signature of Student

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

7-ER	7-ethoxyresorufin
ADI	Australian Defense Industries
AhR	Aryl-hydrocarbon receptor
AMD	Acid mine drainage
ANOVA	Analysis of variance
ANCOVA	Analysis of covariance
ANOSIM	Analysis of similarity
AR	Androgen receptor
ARE	AhR response element
ARNT	Aryl hydrocarbon receptor nuclear translocator
BAF	Bioaccumulation Factor
BCD	Base catalysed decomposition
BCF	Bioconcentration factor
BCI	Below detection limit
CCA	Canonoical correspondance analysis
CPOM	Coarse particulate organic matter
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CYP1A	Cytochrome P450-1A
DCC	Dextran coated charcoal
DCM	Dichloromethane
DDD	Dichloro-diphenyl-dichloroethane
DDE	Dichloro-diphenyl-ethane
DDT	Dichloro-diphenyl-trichloroethane
DES	Diethylstilbestrol
DMSO	Dimethylsulphoxide
DO	Dissolved oxygen
DWG	Drinking water guideline
EDCs	Endocrine disrupting compounds
E_1	Estrone

E_2	17β-estradiol
E_2eq	17β-estradiol equivalent concentration
EE_2	17α-ethynylestradiol
EI	Electron ionisation
EPT	Ephemeroptera, Plecoptera, Trichoptera
ER	Estrogen receptor
ERA	Ecological risk assessment
EROD	Ethoxyresorufin-*O*-deethylase
ETR	Ecotoxicological rating
EWQCP	Eastern Water Quality Control Pond
FPOM	Fine particulate organic matter
GC-MS	Gas-chromotography – mass spectrometery
GL	Gonopodial length
GSI	Gonado-somatic index
Gx	Gonopodial extension
HpCDD	Hepta-chloro dibenzo dioxin
ICP-MS	Inductively coupled – mass spectrometry
ITD	Indirect thermal desorption
LR	Gonopodial length ratio
LOE	Line(s) of evidence
LOI	Loss on ignition
NADPH	Nicotinamide adenine dinucleotide phosphate + H^1
nMDS	Non-metric multi-dimensional scaling
NOAA	National Oceanic and Atmospheric Administration
NSW	New South Wales
OCA	Olympic Coordination Authority
OCDD	Octo-chloro dibenzo dioxin
OCP	Organochlorine pesticides
PAH	Pulycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCDD/F	Poly chlorinated dibenzo dioxins/furans

POPs	Persistent organic pollutants
RBA	Relative binding affinity
RO	Reverse osmosis
SGp	Standardised gonopodial length
SIM	Selected ion monitoring
SIMPER	Similarity percentages
SIMPROF	Similarity profile permutation tests
SL	Standard length
SMA	Standardised major axis
(S)MATR	Standardised major axis tests and routines
SPE	Solid phase extraction
SOP	Sydney Olympic Park
SOPA	Sydney Olympic Park Authority
SWQCP	Southern Water Quality Control Pond
TCDD	Tetra-chlorinated dibenzo-*p*-dioxin
TCDDeq	Tetra-chlorinated dibenzo-*p*-dioxin equivalent concentration
TOC	Total organic carbon
TPH	Total petroleum hydrocarbons
UNEP	United Nations Environment Program
USEPA	United States Environmental Protection Agency
WOE	Weight of evidence
WR	Gonopodial width ratio
WQG	Water quality guideline
WRAMS	Water reclamation and management scheme

Abstract

Disruption to the endocrine systems of wild fauna by anthropogenic compounds (endocrine disruption) has received significant scientific attention over the past 50 years. Compounds with reported reproductive effects (e.g., natural and synthetic estrogens, organochlorine pesticides) have received particular attention due to their potential population level effects. Endocrine disruptors which bind to the aryl hydrocarbon receptor (AhR) (e.g., polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs)) are being increasingly studied. The toxic action of these compounds can be directly (by endogenous metabolisation to mutagenic products) or indirectly (causing carcinogenesis) mediated by the AhR. The presence of these compounds in the environment is cause for ecological concern. The manufacture and/or release of many endocrine disruptors (particularly chlorinated aromatic compounds) have been restricted in many countries but, due to their long half-lives, significant concentrations are still present in the environment.

Sydney Olympic Park (SOP) is constructed on remediated land. Prior to remediation there were significant concentrations of persistent organic pollutants (POPs) (PCBs, PCDDs, organochlorine pesticides) on the site. The remediation effort in the lead-up to the Sydney Olympic Games in 2000 involved the excavation and treatment of large volumes of POP-contaminated soil and sediment, and storage of treated and translocated wastes in containment mounds on the site. A number of wetlands was created during the restoration process and the area is now habitat for native and migratory fauna. It is also an area of high recreational and educational amenity.

This research investigates the presence of endocrine disrupting chemicals (EDCs) in SOP in the post-remediation context. The studies in this research project investigate different lines of evidence from the concentrations of these chemicals, to *in vitro* bioassays, to an *in vivo*

biomarker of exposure, to population and community level assessment of the presence and effects of POPs in the wetlands within the Park. The results of these individual studies form the basis of a weight-of-evidence semi-quantitative ranking of the wetlands within a gradient of contamination at reference sites.

There was no evidence in the water of the wetlands in SOP to support the presence of EDCs with affinity for estrogen receptor (ER) (17β-estradiol equivalency (E_2eq) quantified by an estrogen receptor radioligand binding assay). In the sediments of the wetlands there was quantifiable E_2eq but there was no effect of this potential estrogenicity on the reproductive morphology of the male mosquitofish, *Gambusia holbrooki*. Chemical analysis showed measurable concentrations of ΣPAHs (272 – 14461 ng/g dry weight), ΣDDT (4 – 98 ng/g) and ΣPCBs (5 – 47 ng/g) within the sediments of most of the wetlands in SOP and an *in vitro* bioassay (H4IIE) indicated the presence of compounds able to bind to the AhR in all sediment samples (0.016 – 7.06 ng/g). Both the chemical and *in vitro* bioassay data for sites within SOP were within the range measured for urban impacted sites throughout Sydney. A biomarker of exposure to POPs (CYP1A induction) was measured in fish (mosquitofish) populations inhabiting the wetlands of SOP and was found to be significantly increased above basal level (2308 pmol res/min/mg protein) at one study site (Boundary Ck) (4327 pmol res/min/mg protein). When compared to reference sites around Sydney these were within the range measured at urban reference sites (1211 – 7579 pmol res/min/mg protein).

Benthic macroinvertebrate communities were relatively depauperate in most wetlands and had low taxon richness. While it was not possible to assign the cause of these effects to the presence of organic pollutants, multivariate analysis of the data suggests a correlation between depauperate communities and increasing sediment concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin equivalency (TCDDeq), ΣDDT and Total Organic Carbon. It was not possible to prove that differences between the life-history traits of mosquitofish inhabiting the study sites were due to POP-contamination. Differences are likely to be due to complex interactions of biotic and abiotic factors.

A weight-of-evidence approach synthesising these lines of evidence was developed to semi-quantitatively assess the ecological risk associated with the presence of POPs in SOP. A ranking of the sites revealed that the study sites within SOP fell between the pristine site (Upper Colo) and the heavily POP impacted reference site (Homebush Bay). It was concluded that there appears to be little or no legacy impact of the pre-remediation contamination levels at SOP. The remediation program has, therefore, been successful in returning SOP wetlands to within the chemical and biological bounds expected in an urban impacted wetland. Measured contamination in the created wetlands in SOP suggests current inputs from the catchment. It is recommended that these findings form the basis of ongoing monitoring, particularly of the most POP-affected wetlands, as identified by the weight-of-evidence assessment (Boundary Ck and Lake Belvedere). Further, it is recommended that current sources of POPs in the urbanised catchments upstream of these sites be investigated and these contamination pathways restricted or closed.